Saskatchewan Technology Enhancement Program

The Determination of Depression Storage and Artificially Drained Areas in the Assiniboine Basin Using Satellite Imagery

by

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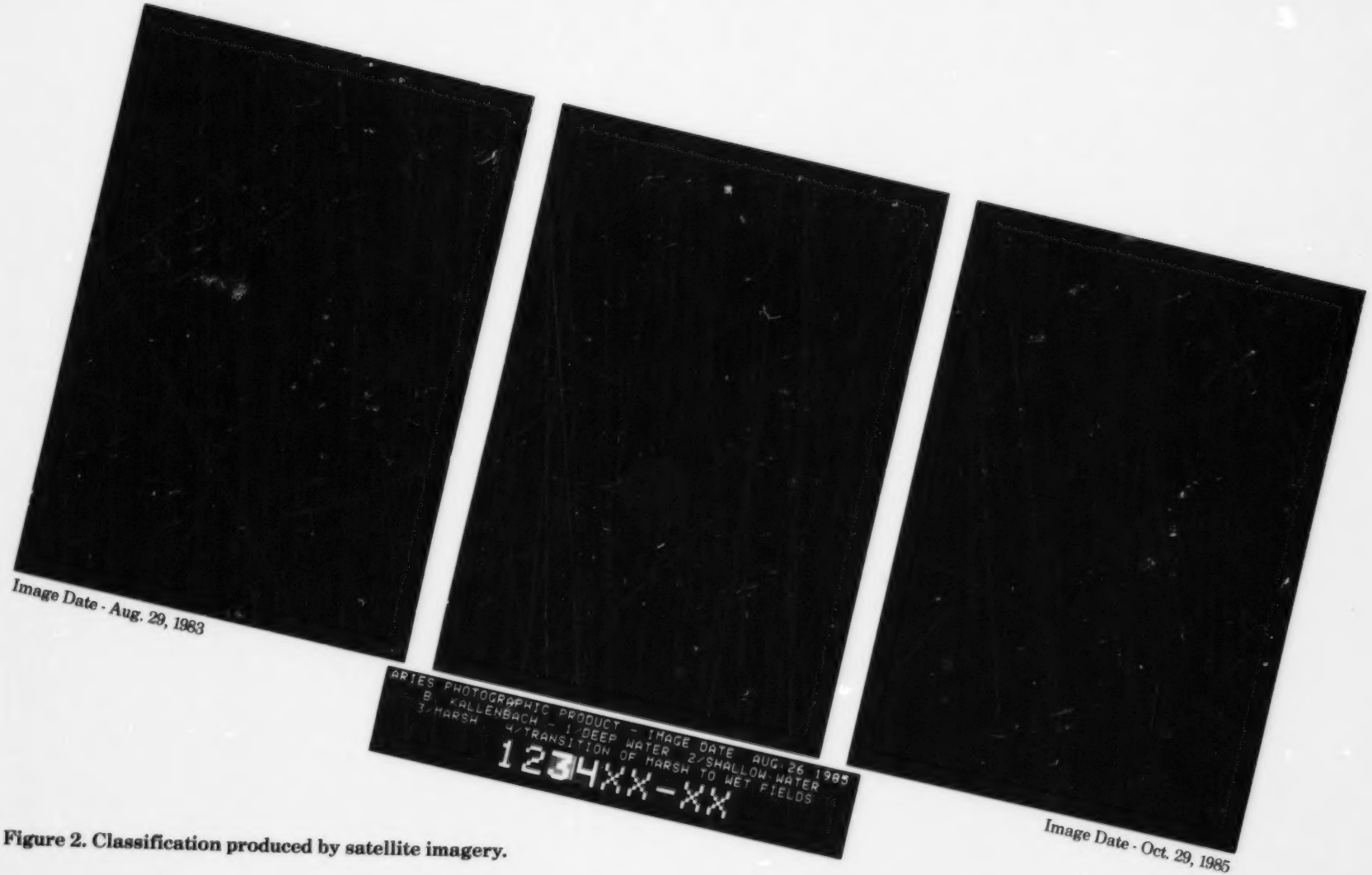
Image Date - Aug. 29, 1983
ARIES PHOTOGRAPHIC PRODUCT - IMAGE DATE AUG. 26 1985
B. KALLENBACH
1/DEEP WATER 2/SHALLOW WATER
3/MARSH 4/TRANSITION OF MARSH TO WET FIELDS
1234XX-XX
Image Date - Oct. 29, 1985

Figure 2. Classification produced by satellite imagery.

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ABSTRACT

In 1984, the Saskatchewan Research Council (SRC) approached the Saskatchewan Water Corporation to participate in a demonstration project involving remote sensing technology. The latter agreed to proceed with two demonstration projects. The first project used Landsat satellite data to determine the area and location of depression storage within a basin. The second project was to determine the extent of artificially drained land within a basin.

The results of the first project could not be readily transformed into a usable format. The result of the second showed that artificially drained land could not be determined at an acceptable level of accuracy using satellite imagery. Based on the results of both demonstration projects, the Saskatchewan Water Corporation has reluctantly concluded that Landsat satellite data cannot, for the moment, contribute to its ongoing projects.

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1. INTRODUCTION

In 1985, the government of Saskatchewan and Energy, Mines and Resources Canada entered into a joint remote sensing Technology Enhancement Program (TEP). This program was designed to assist in transferring remote sensing technology to the public and private sectors in Saskatchewan. The transfer was to be accomplished by undertaking demonstration projects by potential users to help them evaluate the present level of remote sensing technology. The program involved the use of a Dipix Ltd. Digital Analysis System (Aries II)[1] loaned by the Canada Centre for Remote Sensing (CCRS). Mr. Helmut Epp from CCRS was assigned the task of providing training and technical advice on the use of the system and on remote sensing applications to resource management.

The Saskatchewan Water Corporation was invited by the Saskatchewan Research Council (SRC) to submit a proposal as part of the Saskatchewan Technology Enhancement Program (STEP). Saskatchewan Water Corporation agreed to participate and prepared proposals for two projects.

The first proposal was to use satellite imagery to calculate the area and location of depression storage for water present within the Assiniboine River basin. The amount of depression storage was expected to vary over time, based on the antecedent conditions within the basin. This information was to be used in a regression analysis to improve streamflow forecasts.

The second proposal was to use satellite imagery to calculate the area and location of artificially drained land within the Assiniboine River basin. The information was required to evaluate the effect of drainage on the peak flow and runoff volume from the basin. At present, changes in flows due to drainage are an important issue in the east central region of Saskatchewan.

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1) Mention or failure to mention commercial trade names does not imply endorsement or criticism by the Government of Canada or the Government of Saskatchewan.

2. STUDY AREA

The study area was located within the Assiniboine River basin, centered on the town of Canora, in east central Saskatchewan (Figure 1). The area is a rolling, hummocky plain with most of the land under cultivation. Because of the rolling topography, marshes and potholes are created which vary in size from a few square metres to several hectares. The size of the marshes varies relative to runoff, net evaporation, and groundwater table fluctuation. A few are relatively permanent features, while most are only present for a short period of time in the spring and early summer.

Efforts to drain the region beginning in the early 1900's have continued to the present. Over 20 drainage projects were licensed in 1986. In the past 20 years, communities downstream of drainage projects have complained about increased flood levels and have blamed the increases on the drainage projects. To add to the problem, numerous unlicensed drainage projects have also been undertaken in the region.

An initial review of the area indicated that it was well suited for the study due to the topographic features and drainage projects described above. By choosing this region, there would be a reduction of cost and time because analyses for both demonstration projects would be completed using the same satellite images.

Figure 1. Location of the study areas in the Assiniboine River Basin.

3. OBJECTIVES

The objective of the depression storage project was to determine the amount of depression storage present. A regression analysis equation was to be determined to improve streamflow forecasting or be used for general hydrologic investigations.

For the artificially drained land, locations and area calculations were required. This information would be extremely useful in analyzing the impact of drainage on downstream flows.

4. METHODOLOGY

4.1 Depression Storage

Landsat MSS data were chosen for the project (Table 1). The analysis procedures were as follows:

1. A 71 x 85 km subarea of the satellite image was created (see Figure 1).
2. The spectral bands or band combinations were enhanced and tested to aid in the image classification. The best visual enhancements of the depression storage features were used in the final analysis.

Three different procedures, using the enhanced and raw data were employed to produce classifications of the subarea. These included supervised, unsupervised, and parallelepiped classification tasks.

4.2 Artificially Drained Land

Landsat thematic mapper (TM) data was chosen for this project (Table 2).

The following procedures were carried out:

1. A 34 x 65 km subarea of the satellite image was created (Figure 1).
2. Linear, logarithmic, and histogram equalization stretches were used to aid in image classification. The procedures which gave the best visual enhancements of drianage ditches were used in the final anlaysis.
3. Classifications, using the enhanced and raw data channels, were produced with the following procedures:
   a) unsupervised, supervised and parallelepiped classifications using the raw and enhanced spectral bands;
   b) image to image geometric correction using the June 1985 and October 1985 images; and
   c) visual analysis.

Table 1.
Landsat MSS Data Used to Determine Depression Storage Parameters in Part of the Assiniboine River Basin in Saskatchewan.

Date	Image Number
May 15, 1979	38 - 24 (-4 sec)
August 29, 1983	35 - 24
June 4, 1984	35 - 24
June 7, 1985	35 - 24 (-4 sec)
August 26, 1985	35 - 24
October 29, 1985	35 - 24

Table 2
Landsat TM Data Used to Map Artificially Drained Land in Part of the Assiniboine River Basin in Saskatchewan.

Date	Image Number
June 7, 1985	35 - 24, Quadrant II
August 26, 1985	35 - 24, Quadrant II
October 29, 1985	35 - 24, Quadrant II

5. RESULTS AND DISCUSSIONS

5.1 Depression Storage

The best visual enhancements of depression storage features were:

1. a piece-wise linear stretch of band 6 with the greatest stretch in the lower reflectance range of 0 to approximately 30 which is characteristic of open water; and
2. the ratio of band 4 and 7, followed by a piece-wise linear stretch of the ratio.

The unsupervised classification was not entirely successful since it highlighted vegetation differences and not depression storage differences. The results of the supervised classification was partially successful but was not sufficient to classify the smaller depression storage features due to the limitations of the software which did not permit the classification of single pixels. The parallelepiped classification was the most successful and this method was therefore used to classify all imagery of the study area. Four features were classified:

1. Deep water.
2. Shallow water.
3. Marsh.
4. The transition zone from marsh to wet fields.

Area calculations for the above features were tabulated (Table 3). Plots of the classifications were produced at 1:250,000 scale (Figure 2 - frontispiece).

Verification of the results was difficult because only the larger and more permanent marsh areas could be identified on air photos. The presence of smaller marshes was difficult to confirm. The variability of marsh size on different dates could not be confirmed using the aerial photography available to the author.

A multiple linear regression analysis was performed between the depression storage areas listed in Table 3 and the peak spring runoff recorded on the Assiniboine River at Kamsack in the following year. In years where more than one image was available, data from the last image before freeze up was used in the analysis. A strong correlation between peak runoff and various depression storage parameters in Table 3 was not found. One of the reasons was that the depression storage parameters were continually changing during the season due to fluctuating

Table 3.
Depression Storage Parameters Determined For Various Dates of Landsat Data for Part of the Assiniboine River Basin in Saskatchewan.

Date	Deep Water (ha)	Shallow Water (ha)	Marsh (ha)	Transition Zone (ha)	Comments
May 15, 1979	5763	7402	7400	2229	Ice on lakes
August 29, 1983	9079	1663	4936	3151	
June 4, 1984	9689	805	1358	1583	
June 7, 1985	9860	611	823	598	
August 16, 1985	9347	1390	3355	2134	
October 29, 1985	3529	7329	3421	3806	Ice on lakes

water levels. However, since only one or two timely and cloud free images were available in any given year, it was impossible to obtain depression storage at a given time each year. Also, the data base for the regression analysis was too small to provide a reasonable level of confidence. This may, therefore, not be useful for streamflow forecasting until a timely cloud free image can be obtained within a specified 30 day period each year and a large data base becomes available.

Alternative methods for estimating depression storage parameters to apply to a regression analysis program are to: (1) use an antecedent soil moisture model to estimate depression storage parameters or (2) monitor the water level of several permanent or semi-permanent water bodies in the basin of interest. These methods would depend on the meteorological data available. For spring runoff forecasting, water levels would only be required once before the first snowfall. Both of these methods would provide less area coverage than available using satellite data, but the data would be available at any given time.

5.2 Artificially Drained Land

The best visual enhancements of artificially drained land were piece-wise linear stretches on six bands of the TM data and were used in all subsequent analyses.

Unsupervised classification of the enhanced or raw data was not successful since it highlighted vegetation differences and not artificially drained land. Supervised and parallelepiped classifications were used in an attempt to classify the large drainage ditches visible on the image. These methods were not successful because of large variance in reflectances. Image-to-image correction improved highlighting of ditches in some parts of the image but the reflectance variance was still too great to perform a successful supervised classification. In addition, this did not highlight the artificially drained land sufficiently.

Visual analyses of enhanced images allowed the identification of all drainage ditches of 3 m in width or larger, but only in areas where they were not confused with other linear features such as roads and railway lines. Verification of results was not completed because it was apparent that this was not a suitable analysis method.

Alternative methods of determining the extent of artificially drained land included field inspections and low or high level aerial photography. This low level aerial photography is more practical since repeat coverage would only be required every 10 to 20 years.

6. CONCLUSIONS AND RECOMMENDATIONS

Based on the results of the project the following are conclusions and recommendations:

1. Depression storage parameters can be determined using satellite data although this may be difficult for a specific basin, within a certain time frame due to cloud cover problems.
2. The extent of artificially drained land cannot be determined to an acceptable level of accuracy using satellite data.
3. Until there are some advances in analysis techniques and/or higher resolution in satellite data, depression storage parameters and mapping of artifically drained land should be done by conventional methods.
4. Any new types of satellite data should be evaluated for their usefulness in obtaining depression storage parameters and artificially drained land.

APPENDIX A
GLOSSARY

Bands and Channels. The sensors in a multi spectral scanner record a scene in a number of different narrow wave length windows. These windows are called bands or channels.

Channels. See bands and channels.

Contrast Stretching. Raw Landsat data typically occupies only half of the possible reflectance range. For example, one band for an image may have reflectance values ranging from 10 to 100 out of a possible extent of 0 to 255. By applying a contrast stretch, the contrast of an image is maximized, thereby enhancing the visual and digital interpretation capabilities.

Enhancements. Any of several photographic or computer aided processes used to enhance an image to improve image interpretation. Enhancements include contrast stretching, filtering, two band manipulations and multi date combinations.

Histogram Equalization. A histogram equalization is a type of contrast stretch where the reflectance values for an image are redistributed such that approximately an equal number of pixels are set to each reflectance value.

Image. A photographic-like representation of an object generally acquired through electro-optical or electronics means as opposed to a photographic system using film.

Landsat. A series of sun-synchronous earth resource satellites that carry a multi spectral scanner (MSS). The more recent Landsat satellites also carry a high-resolution multi band sensor (TM). The data is returned to earth as electronic signals, recorded on magnetic tape and as photographic images for computer and optical analysis.

Linear Stretch. A linear stretch is a type of contrast stretch where the range of reflectance values for an image are redistributed over the entire extent of possible values. A minimum limit (cutoff point) and maximum limit (saturation point) are chosen for the band. Values less than the cutoff point are set to the minimum value and values greater than the saturation point are set to the maximum value.

Logarithmic Transformation. A log transform is a type of contrast stretch where the reflectance values for an image are redistributed so they fit a normal distribution.

MSS, Multi Spectral Scanner. A scanner that simultaneously records ground reflectance data for four wave length ranges (bands).

Parallelepiped Classification. A classifier which, after being trained upon a certain area, identifies the maximum and minimum digital values in each of two to four spectral bands to define the spectral boundaries of the class. Each pixel in the image is then compared to that class parallelepiped thus defined and if it falls within its bounds. This procedure, may be repeated for any number of classes.

Piece-wise Linear Stretch. A piece-wise linear stretch is a type of contrast stretch which is similar to a linear stretch. However, a piecewise linear stretch allows the amount of stretching to vary over the range of reflectances for an image.

Pixel. In an image, the data is stored in a grid-like format. Each individual grid cell is referred to as a picture element, or pixel for short.

Remote Sensing. The art and science of detection, identification and evaluation of objects while not coming into direct contact with

jects while not coming into direct contact with them. Normally this term is used in context with aircraft or satellite imagery.

Supervised Classification. In a supervised classification, the analyst identifies areas in the image with a known ground cover. The computer then searches the entire image for areas with similar ground reflectances or decision rules and identifies them as one group.

Task. Each step in the image analysis process may require the execution of one or more computer programs. These programs are frequently identified as tasks.

TM, Thematic Mapper. A high-resolution multi spectral scanner sensor which records ground reflectance data for seven narrower wave length ranges (channels) than MSS.

Unsupervised Classification. In an unsupervised classification, the computer scans the entire image and identifies natural groupings or clusters in the ground reflectance values. Classification groupings are usually based on vegetation patterns but may also be affected by soil moisture, slope, aspect, etc. The spectral clusters are identified by comparing their spectral patterns with geographic information about the cover types in the area.